

Remarks/Arguments

A. Pending Claims

Claims 28–32 are currently pending. Claims 28-32 are rejected. Claims 28 and 32 have been amended.

B. The Claims Are Supported by the Specification Pursuant to 35 USC §112, First Paragraph

The Examiner rejected claims 28–32 pursuant to 35 U.S.C. §112, first paragraph, for allegedly failing to comply with the written description requirement. The Examiner states “lines 5-6 of claim 28 recite the limitation of implanting ions of Ar, Ne or He into the regions of the substrate such that ‘regions of the silicon substrate are exposed directly to the implantation source’ is not supported by the specification.” Applicant respectfully disagrees. To expediate prosecution, however, claim 28 has been amended for clarification.

Applicant submits that the claim amendments made herewith are supported by the specification and comply with the written description requirement of 35 U.S.C. §112, first paragraph. Applicant respectfully requests the withdrawal of the Examiner’s rejections on these grounds.

C. The Claims Are Not Obvious Pursuant To 35 U.S.C. 103(a)

The Examiner rejected claims 28-30 under 35 U.S.C. 103(a) as obvious over Japanese Patent No. JP 07-094503 to Yamanishi (hereinafter “Yamanishi”) in view U. S. Patent No. 5,918,116 to Chittipeddi (hereinafter “Chittipeddi”). Applicant respectfully disagrees with the rejection.

In order to reject a claim as obvious, the Examiner has the burden of establishing a *prima*

facie case of obviousness. *In re Warner et al.*, 379 F.2d 1011, 154 U.S.P.Q. 173, 177-178 (C.C.P.A. 1967). To establish a *prima facie* obviousness of a claimed invention, all the claim limitations must be taught or suggested by the prior art. *In re Royka*, 490 F.2d 981, 180 U.S.P.Q. 580 (C.C.P.A. 1974), MPEP § 2143.03.

The Examiner states:

Regarding claims 28 and 29, Yamanishi discloses implanting ions of a chemical species such as argon (Ar) into predetermined regions of a silicon substrate (21) wherein the implanted regions of the substrate are exposed directly onto the implantation source. The surface of the substrate is then oxidized to form a gate oxide layer of non-uniform thickness and MOS transistors are formed over the gate oxide layer. Yamanishi does not explicitly disclose implanting the species at an implantation energy of 2 – 15 keV. However, Yamanishi states that the process parameters of the ion implantation and the oxidation can be tailored according to the thickness of oxide that is desired. Like Yamanishi, Chittipeddi discloses a process of forming gate oxides of non-uniform thickness on a silicon substrate by implanting regions of the substrate with ions of a chemical species in order to increase the oxidation rate of these regions. Chittipeddi discloses that these ions may be implanted at energies ranging from 5 – 500 keV. At the time of the invention, it would have been obvious to one of ordinary skill in the art to implant the ions of Yamanishi with an energy in the range of 5 – 15 keV because Yamanishi states that the ion implantation process parameters may be varied according to the thickness of oxide desired for a particular purpose and Chittipeddi teaches that implantation energies within this range can successfully accomplish an increase in the oxidation rate of a silicon substrate.

Amened claim 28 is directed towards a process for forming a semiconductor device comprising a plurality of MOS transistors at predetermined regions of a silicon substrate. Amended claim 28 states:

implanting, in a predetermined regions of the silicon substrate, a chemical species with an implantation energy between 2 and 15 keV, wherein the chemical species comprises Ne or He;
oxidizing the surface of the silicon substrate to form a gate oxide layer of non-uniform thickness; and
forming MOS transistors at the predetermined regions of the silicon substrate, wherein the oxidized layer at the predetermined regions forms the gate oxide layer of the MOS transistors.

Yamanishi does not appear to teach or suggest the implantation of He and Ne in the range of 2–15 keV). Yamanishi appears to teach a supplementary step of implanting nitrogen ions in the silicon substrate in the range of 25 to 58.8 kV. Referring to Figure 4 of Yamanishi, nitrogen atoms appear to be implanted in a predetermined region of a silicon substrate with an implantation energy of 25 kV and an implantation dose of 5×10^{15} atoms/cm² to form nitrogen-implanted region 23. Yamanishi then appears to teach implantation of argon ions in another region of silicon substrate 21 with an implantation energy of 58.8 kV and an implantation dose of 5×10^{15} atoms/cm² to form argon-ion implanted region 24. A thermal oxidation is then performed, which results in a thin silicon oxide layer 26 and a thick silicon oxide layer 27.

Applicant submits that implanting nitrogen ions in the silicon substrate according to Yamanishi's teachings is disadvantageous to Applicant's invention. Applicant's specification recites:

[A] process has recently been proposed in which a nonuniform thickness oxide layer is grown in a single step. This process consists in forming, on the surface of the substrate, predetermined regions having an oxidation rate reduced by nitrogen ion implantation in these predetermined regions at points where it is desired to obtain a thinner oxide layer, and then in growing a silicon oxide layer by oxidation of the surface of the silicon substrate...

The latter process has serious drawbacks since the high dose of implanted nitrogen ($>10^{15}$ atoms/cm²) inevitably leads to the degradation of the thin gate oxide layer. This drawback is all the more problematic when the implanted regions are in the majority on the substrate and the thinner the oxide layer is thereon (and therefore the more sensitive it is to degradation problems). (Specification, page 2, lines 6–27).

Moreover, the use of chemical species comprising Ne or He in the implantation step results in the formation of a porous silicon substrate, which enhances the diffusion of oxygen and increases the rate of oxidation of the semiconductor crystalline substrate. Applicant submits that the unexpected advantage of using He and Ne in this step to produce the gate oxide layer is neither taught nor suggested by the references taken either alone or in combination.

Applicant submits that Chittipeddi does not appear to teach or suggest implanting Ne or He onto a silicon substrate. Chittipeddi appears to teach the implantation of silicon, fluorine or arsenic. Chittipeddi states, “Epitaxial silicon layer 10 can contain a plurality of device tubs 11 by ion implanting dopants such as boron, phosphorus, arsenic, etc.” (Chittipeddi, column 2, lines 54-56). In contrast, Applicant’s specification recites:

Although the implantation of phosphorous or arsenic increases the rate of oxidation of a silicon substrate, these species have the drawback, however, of being dopants of silicon, something which is not always desirable.
(Specification, page 3, lines 9-13)

The Examiner states: Chittipeddi discloses that these ions may be implanted at energies ranging from 5 to 500 keV....it would be obvious to one of ordinary skill in the art to implant the ions of Yamanishi with an energy range of 5-15 keV because Yamanishi states that the ion implantation process parameters may be varied according to the desired oxide thickness.” Applicant submits however, that Yamanishi does not appear to teach how to adjust these parameters.

Applicant respectfully disagrees that that the relationship between oxide thickness and implantation parameters (i.e. dose and energy) is intuitive. For example, Table I in Applicant’s specification lists implantation dose and energy to produce an implant thickness. An implantation dose and energy of Ne or He is 5×10^{14} atoms/cm² and 2 keV produces an oxide layer with a thickness of 5.66 nm. When the implantation energy is increased to 80 keV, however, a thickness of a resulting oxide layer is increased slightly to 6.00 nm. Thus, increasing the implantation energy by a factor of 40 has only a minimal effect on oxide thickness.

Conversely, under conditions where an implantation dose and energy of Ne or He are 5×10^{16} atoms/cm² and 10 keV, respectively, the thickness of the oxide layer formed is 12.3 nm. When the implantation energy is elevated to 80 keV however, the thickness of the oxide layer formed decreases by 10.6% from 12.3 nm to 11.00 nm.

Applicant submits that, at the time the invention was made, the range of optimal values for implantation energy and Ne or He implantation dosage used to achieve a desired oxide layer thickness would not have been obvious to one of ordinary skill in the art. Indeed, the implantation of Ne or He results in damaged regions of the silicon substrate that are comprised of Ne or He bubbles within an amorphous layer of the silicon. During the thermal treatment required for oxide layer growth, isotropic diffusion of these bubbles and re-growth of the amorphous silicon layer occurs. Both these phenomena lead to a decrease in the thickness of the damaged region and to the formation of larger argon bubbles by percolation. These phenomena depend on thermal conditions applied (such as oxidation temperature and temperature ramp up and ramp down rates) and are complex, thus making prediction of the thickness under varying conditions extremely difficult.

For at least the reasons cited above, Applicant submits that neither Yamaishi nor Chittipeddi, taken separately or in combination, teach or suggest the combination of features of claim 28. Applicant further submits that claims 28–30 are patentable over the cited art pursuant to 35 USC §103(a), and respectfully requests the removal of rejections on these grounds.

The Examiner rejected claims 31 and 32 pursuant to 35 USC §103(a) as being unpatentable over Yamanishi and Cittipeddi in view of US Patent No. 5, 215, 934 to Tzeng (hereinafter “Tzeng”). Applicant respectfully disagrees with these rejections.

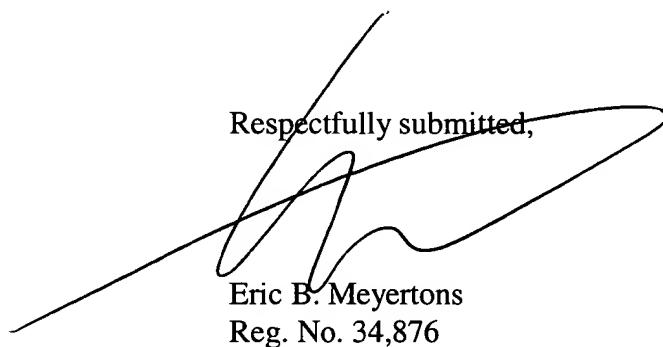
If an independent claim is nonobvious under 35 U.S.C. 103, then any claim depending therefrom is nonobvious. *In re Fine*, 837 F.2d 1071, 5 USPQ2d 1596 (Fed. Cir. 1988).

Applicant submits that, for at least the reasons cited above, the combination of cited art fails to render amended claim 28, or any claims depending thereon, obvious. Applicant respectfully requests withdrawal of the rejection of claims 31 and 32.

D. Additional Remarks

Based on the above, Applicant submits that all claims are in condition for allowance.
Favorable reconsideration of the claims is respectfully requested.

It is believed that no fees are due in association with the filing of this document. If any extension of time is required, Applicant hereby requests the appropriate extension of time. If any fees are required, please charge those fees to Meyertons, Hood, Kivlin, Kowert & Goetzel, P.C. Deposit Account Number 50-1505/5310-03000/EBM.

Respectfully submitted,

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